OPTICS Third Edition

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ADDISON-WESLEY

An imprint of Addison Wesley Longman, Inc.

Reading, Massachusetts • Menlo Park, California • New York • Harlow, England
Don Mills, Ontario • Sydney • Mexico City • Madrid • Amsterdam

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Text Design: *HRS Electronic Text Management*
Composition: *HRS Electronic Text Management*
Illustration: *Oxford Illustrators and HRS Electronic Text Management*

Library of Congress Cataloging-in-Publication Data

Hecht, Eugene
Optics / Eugene Hecht; — 3rd ed.
p. cm.
Includes index.
ISBN 0-201-83887-7
1. Optics. II. Title.
QC355.2.H42 1998
535—dc20

3 4 5 6 7 8 9 0 - MA - 009998

shadows (*Purkinje figures*) cast by the blood vessels on the sensitive retinal layer.

Accommodation

The fine focusing, or **accommodation**, of the human eye is a function performed by the crystalline lens. The lens is suspended in position behind the iris by ligaments that are connected to a circular yoke composed of the **ciliary muscles**. Ordinarily, these muscles are relaxed, and in that state they pull outward radially on the network of fine fibers holding the rim of the lens. This draws the pliable lens into a fairly flat configuration, increasing its radii, which in turn increases its focal length [Eq. (5.16)]. With the muscles completely relaxed, the light from an object at infinity will be focused on the retina (Fig. 5.93). As the object moves closer to the eye, the ciliary muscles contract, relieving the external tension on the periphery of the lens, which then bulges slightly under its own elastic forces. In so doing the focal length decreases such that s_i is kept constant. As the object comes still closer, the yoke of ciliary muscles becomes more tensely contracted, the circular region they encompass gets still smaller, and the lens surfaces take on even smaller radii. The closest point on which the eye can focus is known as the **near point**. In a normal eye it might be about 7 cm for a teenager, 12 cm or so for a young adult, roughly 28 to 40 cm in the middle-aged, and about 100 cm by 60 years of age. Visual instruments are designed with this in mind, so that the eye need not strain unnecessarily. Clearly, the eye cannot focus on two different objects at once. This will be made obvious if, while looking through a piece of glass, you try to focus on it and the scene beyond at the same time.

Mammals generally accommodate by varying the lens curvature, but there are other means. Fish move only the lens itself toward or away from the retina, just as the camera lens is moved to focus. Some mollusks accomplish the same thing by contracting or expanding the whole eye, thus altering the relative distance between lens and retina. For birds of prey, which must keep a rapidly moving object in constant focus over a wide range of distances as a matter of survival, the accommodation mechanism is quite different. They accommodate by greatly changing the curvature of the cornea.

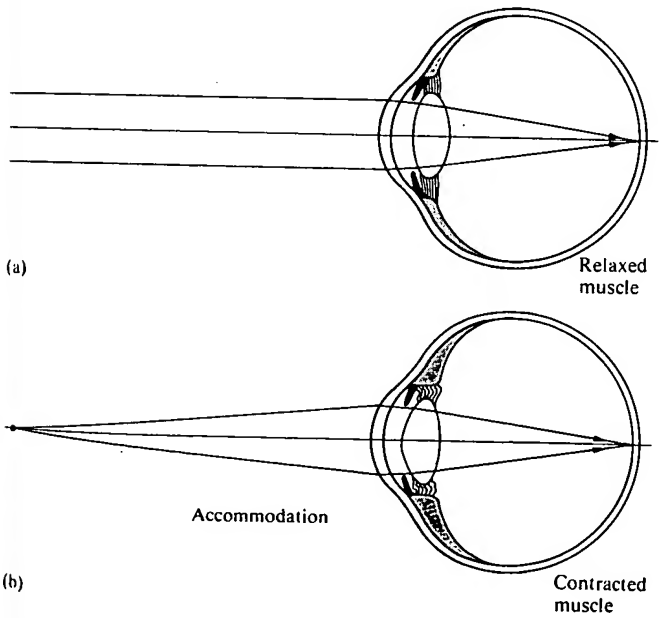

FIGURE 5.93 Accommodation—changes in the lens configuration.

5.7.2 Eyeglasses

Spectacles were probably invented some time in the late thirteenth century, possibly in Italy. A Florentine manuscript of the period (1299), which no longer exists, spoke of "spectacles recently invented for the convenience of old men whose sight has begun to fail." These were biconvex lenses, little more than variations on the handheld magnifying or reading glasses, and polished gemstones were no doubt employed as lorgnettes long before that. Roger Bacon (ca. 1267) wrote about negative lenses rather early on, but it was almost another two hundred years before Nicholas Cusa first discussed their use in eyeglasses and a hundred years more before such glasses ceased to be a novelty, in the late 1500s. Amusingly, it was considered improper to wear spectacles in public even as late as the eighteenth century, and we see few users in the paintings up until that time. In 1804 Wollaston, recognizing that traditional (fairly flat, biconvex, and concave) eyeglasses provided good vision only while one looked through their centers, patented a new, deeply curved lens. This was the forerunner of modern-day meniscus (from the Greek *meniskos*, the diminutive for moon, i.e., crescent) lenses, which allow the turning eyeball to see through them from center to margin without significant distortion.